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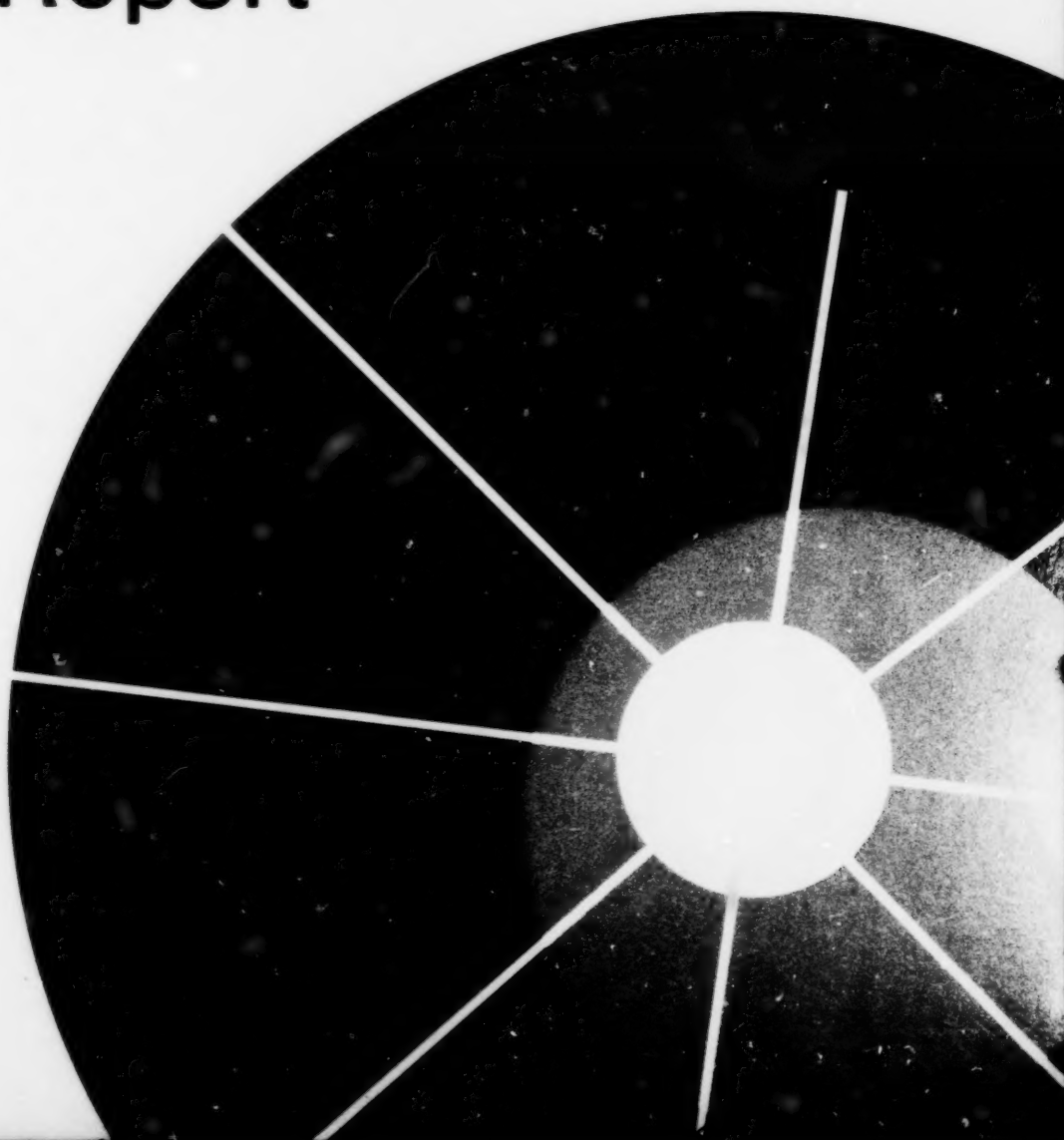
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Canada - Saskatchewan Renewables — Conservation Demonstration Program

Final Report





CANADA-SASKATCHEWAN CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

On March 18, 1980, the governments of Canada and Saskatchewan entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement, which terminates March 31, 1984, funds the development and demonstration of a wide range of conservation and renewable energy technologies. The program is funded on an equal cost-shared basis by Canada and Saskatchewan, and is administered by Saskatchewan.

The objectives of CREDA are:

- To develop and demonstrate promising new technologies which exploit renewable energy resources, conserve energy, or make its use more efficient;
- To create employment in new or existing industries;
- To develop broad public awareness of the potential of renewable energy and energy conservation technologies.

This report outlines the results of a project funded by the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, and the Government of Canada as represented by Energy, Mines and Resources Canada, under the terms of the Renewables-Conservation Demonstration Program, and contracted with the party identified herein.

However, neither the Government of Saskatchewan as represented by Saskatchewan Energy and Mines, nor the Government of Canada as represented by Energy, Mines and Resources Canada, accept liability for any errors, omissions, or inaccuracies that may be included in or derived from this report, nor do they assume any liability with respect to the use of, or actions resulting from the use of, any information contained in this report.

The Moose Jaw Conservahome

The Retrofit and Rehabilitation of a 1976 Platform-Framed Single-Storey House with Full Concrete Basement

**Final Technical Report
on a Renewables-Conservation Demonstration Program Project**

**Conducted By
The Saskatchewan Research Council**

**And Supported By
Saskatchewan Energy and Mines
and
Energy Mines and Resources Canada**

Project Leaders: Dave Eyre and Dave Jennings

**Miscellaneous
Report FP-16**

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This report gives details of the retrofit and rehabilitation work conducted on a house in Moose Jaw, Saskatchewan, as part of the Conservahome Project. This project involved the retrofit and rehabilitation of six houses of various ages and styles, and was funded by CREDA, the federal-provincial Conservation and Renewable Energy Demonstration Agreement. For further details of this project the reader is referred to the Overview Report, which is the first in this series of reports on the project.

The city of Moose Jaw is located in south-central Saskatchewan. It was chosen for the Conservahome Project on the basis of its fairly large population, which would add to the demonstrational value of the project.

Several houses were being offered for sale at the time of house selection. From a short-list of six, five were rejected as being either too expensive or poorly located for demonstrational purposes. The selected house was built in 1976 in a new residential area. The location was suitable for the demonstrational phase of the project, and the price was very low for a house of its age and condition.

The Conservahome Project included three houses built after 1960. These were similar in the main structural details. For the purposes of demonstration it was decided to adopt three different levels of retrofit on the three houses. The Prince Albert Conservahome was chosen for the high-level retrofit and the Yorkton Conservahome for medium-level retrofit. The Moose Jaw Conservahome was chosen for low-level retrofit, as befitted its newness and its relatively high level of thermal efficiency to start with.

At the time of the project, homeowners had access to two programs offering financial assistance for the thermal upgrading of houses: the first was the federal CHIP Program and the second was the provincial Warm-Up loan program. Together, these made a sum of about \$2,000 available to homeowners. The Moose Jaw house was too new to qualify for the CHIP grant, but nevertheless it was felt that the combined sum of

\$2,000 would make an appropriate cost target for the low-level retrofit on this house.

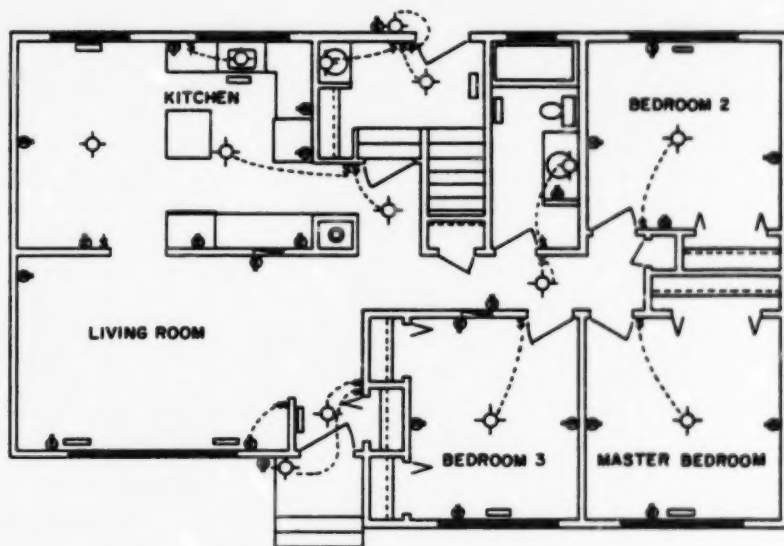
The Moose Jaw Conservahome is therefore of interest as an exercise in low-level retrofit, in which the majority of costs could be covered by existing government funding programs. With such cost constraints the retrofit options are somewhat restricted, and on this house consisted of sealing techniques and moderate upgrading of insulation levels in the attic and basement.

The house is located at Lot 7, Block 286, Plan 74-MJ-12299 of the Caribou Heights Addition. The front of the house faces north on an east-west street. The rear of the house has good solar access across an un-landscaped back yard. The Caribou Heights Addition is a quiet residential area on relatively high ground in the north-west area of Moose Jaw. The water table was judged to be low and the soil type was not conducive to basement problems.

On investigation it was found that the house was a standard 'kit' design available through a manufactured homes dealership. Plans of the house were purchased from the local dealer, thereby eliminating the need to conduct detailed measurements on the house.

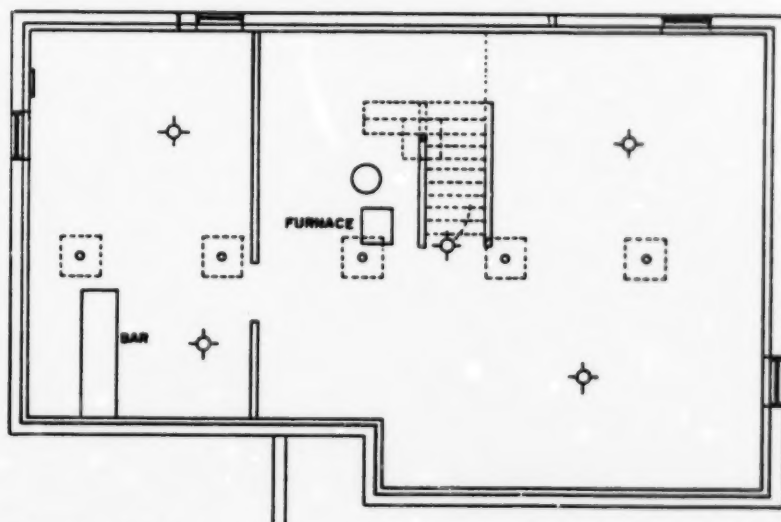
The house consists of a single-storey platform-frame structure on a full concrete basement, and was built in 1976. The plans and sectional view of the house are shown in figure 1 on the following two pages. These are taken from the dealer's plans and may differ slightly from the as-built dimensions. The floor plan area was 106.8 m².

When the house was purchased for the project it was slightly over four years' old. It had been maintained in good condition and required only a small amount of rehabilitation. The house was essentially in its original form with little evidence of modification. The basement walls had been framed and insulated, but it was believed that this work was done at the time of construction. Recent modifications, consisting mainly of finishing work, were of low quality and could be removed without detracting from the value of the house.



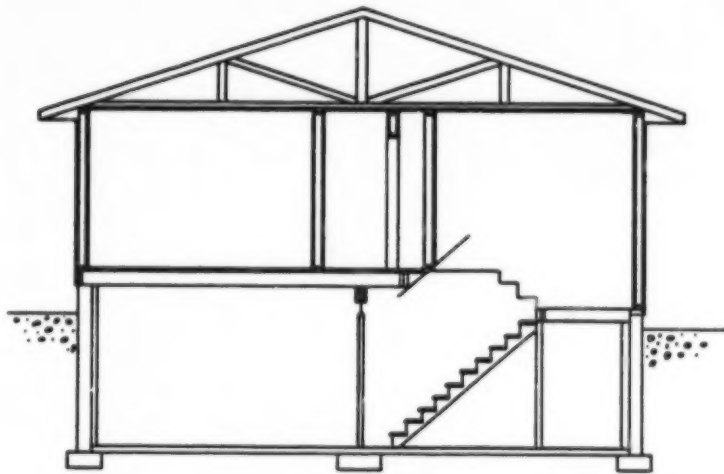
FLOOR PLAN

Figure 1
Plans and sectional
View



BASEMENT PLAN

Continued:



SECTIONAL VIEW LOOKING EAST

Figure 1
Continued.

The house had a natural gas forced-air furnace and a natural gas DHW heater. The measured thermal efficiency of the furnace was 66.2% - a relatively low figure. The house was purchased after the occupants had left and it was difficult to establish the occupancy patterns. It was known that the same family had lived in the house since it was built, and the occupancy is believed to have varied from three to four people.

Natural gas and electricity bills were obtained from the Saskatchewan Power Corporation for the year beginning October 9, 1978. The natural gas billings were based on quarterly meter readings, with estimates on the months in between. Therefore there were only five precise meter readings for the full year. This made it difficult to isolate the gas consumptions of the furnace and the DHW heater. Based on the gas consumption for the period July 12 to October 12, 1979, the annual gas consumption of the DHW unit was estimated to be 1161 m³, giving the following breakdown of gas consumption for the year:

Space heating (natural gas)	3262 m ³
DHW heating (natural gas)	1161 m ³
Total annual gas consumption	4423 m ³

The annual heating degree-day figure for Moose Jaw is 5435 °C.d, based on the thirty-year average, and was 6036 °C.d for the one-year period covered by the fuel bills. The climate in the period was therefore appreciably more severe than the average. The two heating degree-day figures were used to correct the space heating consumption to average annual conditions, giving:

Space heat consumption (average year) 2937 m³

The total electrical consumption in the same one-year period was 9762 kWh, corresponding to an average rate of 26.8 kWh per day.

The DHW gas usage was relatively low for a family of three-to-four, and may indicate that they were on an extended holiday in the period July to October 1979. The electrical consumption was somewhat higher than the average for a family of this size; the average consumption falls in the range 22 to 25 kWh.

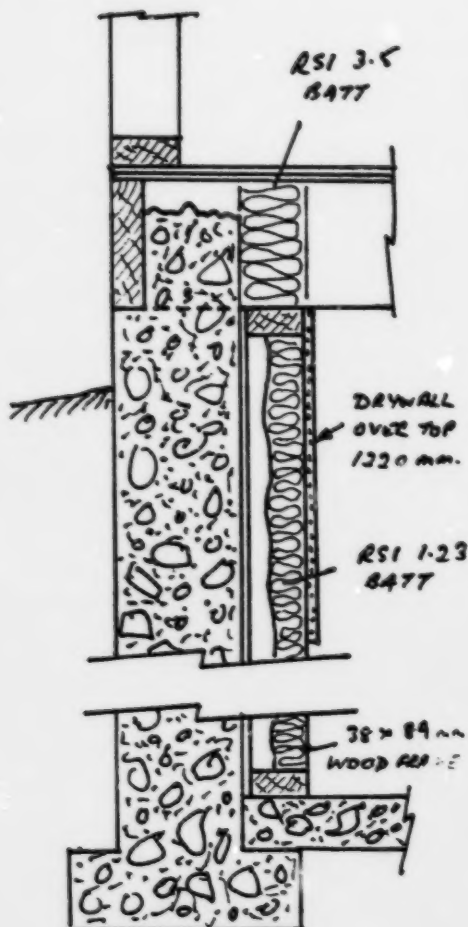
The space heating requirements were calculated theoretically, using the known dimensions of the house and the estimated thermal resistances of the various parts of the house envelope. This gave:

Calculated annual space heat requirement: 98.3 GJ

With a furnace efficiency of 66.2% this corresponds to a space heating gas consumption of 3982 m³, which is 36% higher than the figure of 2937 m³ derived from the fuel bills. The discrepancy is believed to be due to the errors in breaking down the gas bills into their DHW and space heating components, together with an accumulation of small errors in the theoretical calculation.

Based on the fuel bills and the measured thermal efficiency of the furnace, the annual space heating demand of the house was therefore 68.7 GJ. This is a relatively low figure for a house of this size (106.8 m³ plan) and indicated that the house already had a fairly high level of thermal efficiency. This meant that it would be correspondingly harder to achieve higher levels of thermal efficiency by retrofitting.

4.1 Assessment



The concrete floor was sound, with no cracks. The foundation wall appeared to be equally sound, though parts of it were obscured by development and could not be inspected.

The foundation wall had been covered all round the perimeter with a 38 mm x 89 mm wood frame wall, with variable stud spacings, but mostly 600 mm on centres. Kraft-backed glass fibre batt (RSI 1.23) had been installed to the full height of the wall and then the top section of the wood frame had been covered with 12 mm drywall, to a depth of 1220 mm. The bottom section of the frame, to a height of about 1066 mm, was left uncovered. The batt insulation was exposed and was found to be loosely installed - it had not been stapled to the studs in the usual way. Several batts were lifted to allow inspection of the foundation wall. The condition was found to be good, but the lower section of wall had not received any moisture barrier treatment.

Sections of glass fibre batt (RSI 3.5) had been installed between the joists above the wood frame. When sections of these were removed, it was found that the joists had been set into the foundation wall according to customary Saskatchewan practice. The gap between the top of the foundation wall and the sub-floor was about 50 mm. The top of the foundation wall was rough and irregular, and no attempt had been made to seal or insulate at this point.

A room had been developed across the east end of the basement. A partition wall had been constructed as shown in figure 1. The partition wall and the wood frame around the foundation wall had been fully covered with either panelling or a mixture of drywall and 22 mm x 89 mm spruce trim. The ceiling had been strapped and tiled. The quality of this developmental work was poor. It could be removed easily and without detracting from the value of the house.

An inspection of the main storey floor joist design revealed two defects: the overlap of the joists above the main support beam was insufficient, and it was estimated that there was some risk of the joists scissoring over the long term; also there was one less support column than called for in the dealer's drawings. These defects may have contributed to the ceiling cracks described later.

In an overall assessment, the basement was judged to be very good from the standpoint of thermal efficiency, though it had three minor defects:

- There was a lack of air-sealing and insulation at the top of the foundation wall.
- It would have been advisable to have some kind of moisture barrier on the foundation wall, from floor level up to a height corresponding to the grade level outside.
- The insulation was not as effective as it could have been, since it did not completely fill the cavities within the wood framed wall.

4.2 Retrofit Alternatives

The house was to be given a low-level retrofit, and the retrofit options are therefore discussed within this context.

The required work in the basement could be divided into four parts:

- Sealing and improving the insulation at the top of the foundation wall.
- Generally improving the level of insulation in the wood frame walls.
- Providing a moisture barrier from the foot of the foundation wall to grade level.
- Installing a vapour barrier and drywall over the bottom section of the wood frame.

The last two items could be regarded as rehabilitation rather than retrofit, since they involved modif-

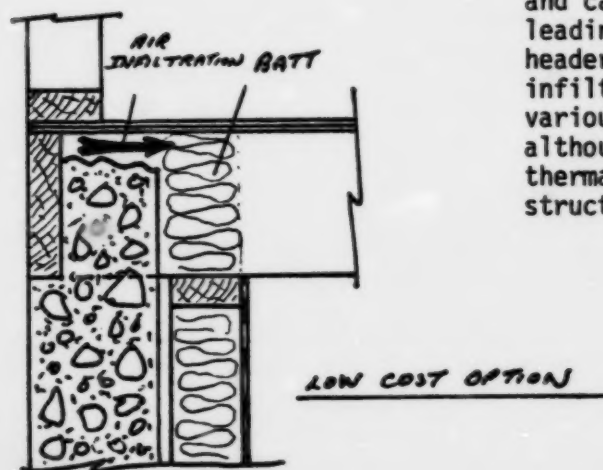
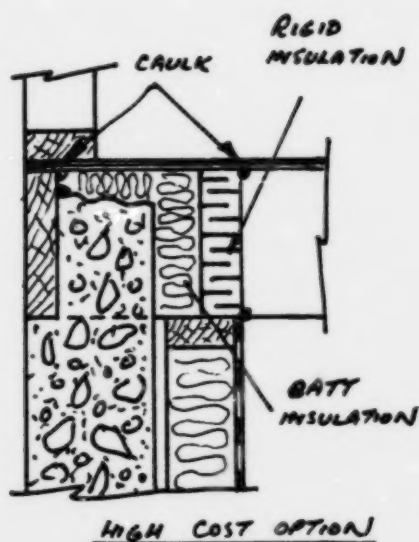
ication of the basement development to bring it up to the standards of good building practice.

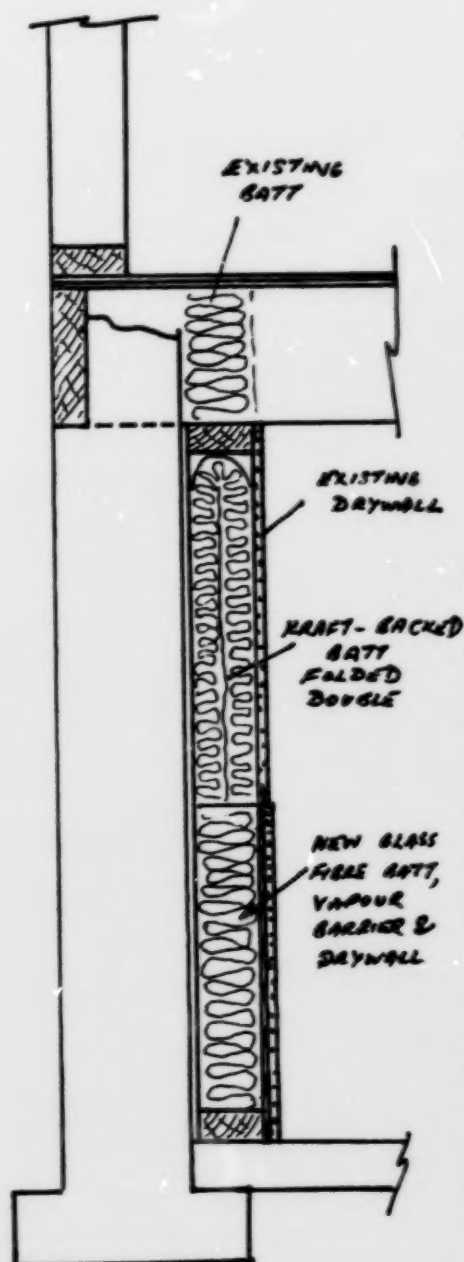
There were two ways of dealing with this work: the first was to remove the existing drywall and insulation and start again from scratch (the high cost option); the second was to try to accomplish the work with minimum disturbance to the existing development (the low cost option).

4.3 Factors affecting the choice

The choice was eventually dictated by costs. In the first place, contractors were asked to bid on the high cost option. The costs were found to be too high (around \$1,500), and it was decided to pursue the low cost option. A re-appraisal of the retrofit design was conducted with the cooperation of the selected contractor, to devise ways of reducing the costs of the basement retrofit. The following decisions were made:

- It would have been too expensive to seal and insulate at the top of the foundation wall, mainly because of the difficulty of working in this area. The major part of the costs would have been incurred in sealing the various air leakage points and in providing an air-vapour barrier over the insulation. It was therefore decided to retain the existing work, without modification, at this point. Without an air-vapour barrier over the insulation there would be a tendency for moisture to penetrate to the header and cause progressive moisture accumulation, leading eventually to moisture damage at the header. However, this would be resisted by the infiltration of dry outside air through the various cracks around the header. Therefore, although this part of the house would have poor thermal performance, the risk of long-term structural damage was expected to be minimal.





- It would have been very difficult - and costly - to install an effective moisture barrier without removing the existing drywall and insulation. It was therefore decided to omit the moisture barrier. It was felt that, by retaining the existing design at the top of the framed wall, there would be an adequate safeguard against moisture damage to the wood frame. Any moisture seeping through the concrete foundation wall would be dissipated (by diffusion) through the batt insulation above the wood frame wall.
- Since the existing kraft-backed batt insulation had not been stapled in position, it could be removed, folded double, and re-inserted behind the existing drywall. This would approximately double the insulation level over the top half of the wall, and would leave an easily accessible space for installing new batt insulation at the bottom of the wall. It should be noted that, when insulation is compressed, it loses some of its effectiveness - depending on the degree of compression. In this instance there was enough space to double the kraft-backed batt without excessive compression penalties.

4.4 Details of the upgrading work

The partition wall and all finishing work were removed, leaving the insulated stud frame with the top half covered with drywall.

The existing kraft-backed batts were removed by pulling them downwards and outwards. They were then folded double, with the vapour barrier surface on the outside, and inserted behind the existing drywall.

The bottom section of the wall, with the exposed stud frame, was insulated with glass fibre batt (RSI 2.1). A vapour barrier of 0.150 mm polyethylene sheet was installed over the exposed wood frame. No special care was taken to seal the vapour barrier, since an airtight vapour barrier would not have been of any benefit in this situation (because of the absence of any air-vapour barrier seal at the header). The exposed section of wall was then finished with drywall screwed in place.

5.1 Assessment

The exterior walls consisted of a 38 mm x 89 mm wood frame, on 400 mm centres, insulated with RSI 2.1 glass fibre batt. The exterior surface was finished mainly with horizontal wood siding, painted in off-white. Parts were finished with stained, vertical cedar siding. All exterior surfaces were in good condition.

The interior surface was finished with 0.05 mm polyethylene vapour barrier and 12 mm drywall. The drywall was generally in good condition, with some small nail holes and occasional gouges. A small amount of condensation staining was noted on the drywall under some windows, but not enough to cause any concern about excessive humidity levels in the house.

5.2 Retrofit Alternatives

Since this house was restricted to low-level retrofit, all re-insulation options were ruled out, as being far beyond the allowable costs. The retrofit options were therefore limited to simple sealing work.

With the exception of the door and window seals, which are treated in a later section, the main air leakage points in the exterior walls could be divided into three categories:

- Electrical outlets in exterior walls.
- Breaks in the vapour barrier around window and door frames.
- Cracks between the wall sill plate and the sub-floor.

5.3 Factors affecting the choice

The electrical outlet sealing could be conducted at minimal cost, and it was therefore decided to include this in the air sealing work.

The door and window frames were finished with a plastic trim with a simulated wood finish. This was nailed lightly in place and could be removed and replaced at low cost, without requiring any significant rehabilitation afterwards. It was therefore decided to include these areas in the air sealing work.

To properly air seal the gap at the wall sill plates it would have been necessary to remove the baseboards. This would have involved some repair work afterwards, and was judged to be marginally too costly to be included in the sealing work. In making this decision, some thought was also given to the risk of moisture damage. Moisture damage occurs mainly as a result of exfiltration of moist house air through the various air leakage openings. In most houses, the exfiltration process is strongest at the upper ceiling level, and infiltration is strongest at basement floor level. At the mid-height of the house, at a position corresponding roughly with the main floor level, the pressure differences across the house envelope are negligible, and there is very little driving force for air leakage. When air leakage does occur at the sill plates, it tends to be inwards rather than outwards. Therefore, the incoming, dry outside air tends to inhibit any moisture damage action at this point.

5.4 Details of the upgrading work

The cover plates were removed from all electrical outlets in the exterior walls. A generous bead of caulk was then applied around the electrical outlet opening. The cover plate was then replaced and any excess caulk was removed. When sealing an electrical outlet in this way, it is important to use a caulk with low adhesive properties, so that the cover plate can be removed easily when necessary.

The trim was removed from around window and door frames. This revealed gaps of varying widths around the frames. Pieces of glass fibre batt were worked into the large gaps, then strips of duct tape were applied around the frames, to seal the air gap between

the frames and the surrounding drywall. The trim was then replaced and minor repairs were conducted on nail holes and other damage. Note that when duct tape is used in this way, there is a risk that it may lose adhesion over a period of years, and lift off the drywall or frame. It was felt that the nailed trim would prevent this from happening to any great extent.

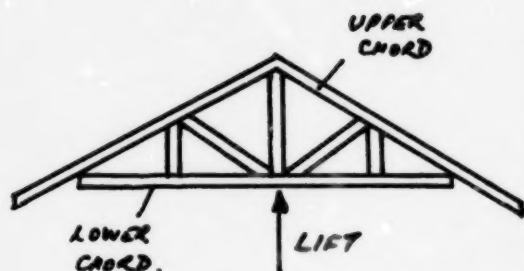
6.1 Assessment

The roof had a 5:12 pitch with gable ends. There was fairly good access to most parts of the attic. All parts of the structure appeared to be in good condition, with no significant signs of moisture damage. In a house of this age (less than 4 years old at that time) there should be little evidence of cumulative moisture damage anyway, unless the house has a fairly serious exfiltration problem.

The ceiling vapour barrier consisted of 0.05 mm polyethylene sheet material, installed to relatively high standards. The polyethylene sheet was continuous or overlapped across the top of the partition walls, a good practice which is rarely encountered. Apart from this, there were major sources of air leakage around the various penetrations into the attic space, including the furnace chimney, the vent stacks, the attic hatch, electrical ceiling fixtures and cable runs through the top plates of partition walls.

On further investigation, the attic ventilation was judged to be far too high, and may have been the main reason for the absence of moisture damage. The soffits on all four sides of the house were fitted with an almost continuous ventilation strip, about 50 mm wide, with a flyscreen. It was felt that this would promote excessive air movement through the attic and induce an unnecessary increase in the heat loss through the ceiling. Further evidence of excessive air movement was provided by the large quantities of dust on the ceiling insulation. The quantity of dust was surprisingly large for a four-year-old house, and was far higher than had been encountered in any of the other Conservahomes - some of which were about 60 years old.

The ceiling insulation consisted of glass fibre batt (RSI 3.5) which protruded slightly above the tops of the ceiling trusses. Faint discolourations were noted on the ceiling paint (viewed from inside the house) near the tops of partition walls. This suggested that there were cold spots in these areas, possibly due to air gaps under the batts. An inspection of the batt installation confirmed this.



Along the centre of the ceiling, in line with the central bearing partition wall, there was a fine crack in the drywall, about 1200 mm long. It was assumed that this was caused by the mechanism of 'truss lift'. In a pre-fabricated truss system, the upper and lower chords operate at significantly different temperatures. As a result, they have different moisture levels in winter, and will display differential expansion and contraction. This differential movement produces a lifting effect on the central section of the lower chord, which may become visible in the form of cracks in the centre of the ceiling. The severity of the effect depends on the temperature difference between the upper and lower chords, and is therefore dependent on the thermal resistance of the ceiling insulation.

In this instance, it was felt that the RSI 3.5 batt insulation was maintaining the lower chords at a relatively high temperature, even though the batt did not completely cover the tops of the chords. If this hypothesis was correct, then it meant that the truss lift effect might be aggravated by the addition of more insulation.

The ceiling contained one other feature that required special attention, namely a recessed pot light above the kitchen sink. For safe operation, recessed light fixtures must be able to dissipate their heat through the metal receptacle. If insulation is piled around this receptacle the heat will not be able to escape as freely, and the temperature inside the receptacle may increase to the point where there is a fire hazard. Such recessed pot lights are therefore a potential hazard in a ceiling retrofit.

6.2 Retrofit Alternatives

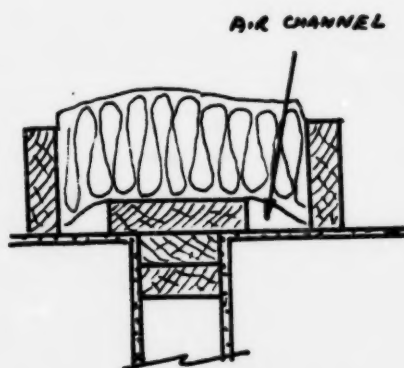
When a house has an open, accessible attic space, ceiling insulation is one of the most cost-effective ways of upgrading the thermal performance of the house. However, this should not be done without first sealing the various air leakage openings in the ceiling. Generally, exfiltration air flow is strongest at the top of the house envelope - mainly through the ceiling. The exfiltrating air carries

moisture through the house envelope into the attic space, where it may accumulate and cause moisture damage. When insulation is added to the ceiling, the attic air space will operate at a reduced temperature, and in some instances this may increase the risk of moisture damage by promoting a more rapid condensation of the moisture. It is therefore good practice to seal the air leakage points at ceiling level before re-insulating the attic.

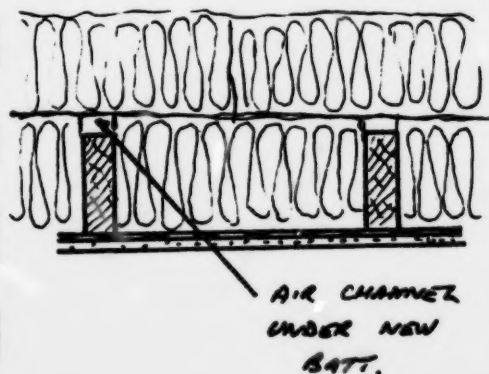
In this instance, the air sealing and re-insulation work could be conducted within the low-cost budget of the retrofit work, and it was therefore decided to pursue these two options.

6.3 Factors affecting the choice

When insulation is added to a ceiling, there is a risk that it may be piled against the eaves and block the soffit ventilation channels. If this happens, the flushing action of the ventilation air may be reduced to the point where moisture starts to build up in the attic. In this instance the attic ventilation was judged to be excessive to begin with. It was therefore decided to encourage the piling of insulation at the eaves. This would have two beneficial effects: first, it would reduce the heat losses due to excessive air movement through the attic; secondly, it would reduce the heat losses due to airflow over the top plates of the exterior walls, where the thermal bridging is particularly strong.

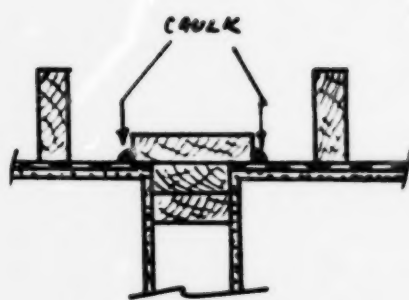


It was decided to re-insulate with loose-fill rather than batt insulation, because of the better filling that can be obtained with loose fill. In this instance there would have been a possibility of airflow under the batts, both at the top of some partition walls and along the tops of the ceiling trusses, as shown in the sketches alongside.



The air sealing work was expected to reduce moisture infiltration into the attic to a negligible level, therefore the risk of moisture build-up was expected to be remote. Accordingly, it was permissible to use all types of loose-fill insulation, including those that were prone to moisture attack.

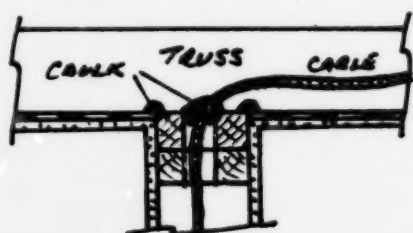
6.4 Details of the upgrading work



The existing batt insulation was removed at various places around the attic to give access to the tops of partition walls and ceiling fixtures.

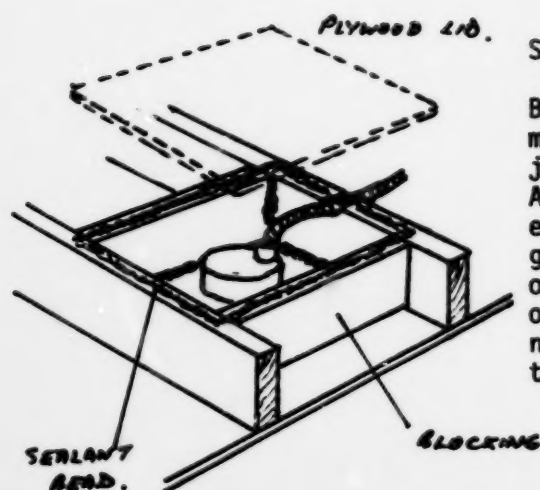
Vapour barrier sealing:

Where the vapour barrier was discontinuous at the top of partition walls and exterior walls, the contractor was asked to apply caulk to make an airtight seal at the gaps, according to the details given in the sketches alongside. Caulk was applied around electrical cables, where they passed through the top plates of partition walls.



Recessed pot light:

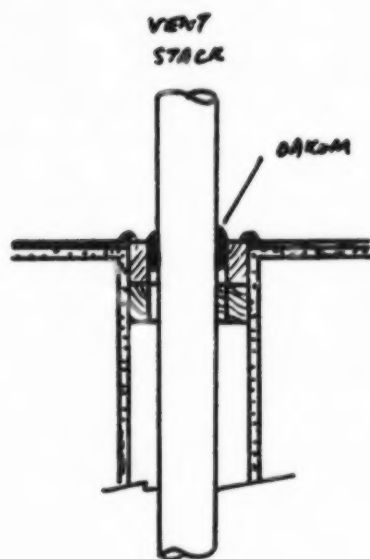
This was removed and replaced with a ceiling-mounted fluorescent unit, selected for its energy conservation performance.



Sealing around electrical receptacles:

Blocking was installed between ceiling trusses, to make a four-sided frame around each receptacle. The joints on this frame were then sealed with caulk. A groove was cut in the top of the frame to accept electrical cables. These were then fixed inside the groove and caulked to make an airtight seal. A bead of sealant was then run continuously around the top of the frame, and a piece of 12 mm plywood was then nailed in place to make an airtight enclosure over the receptacle.

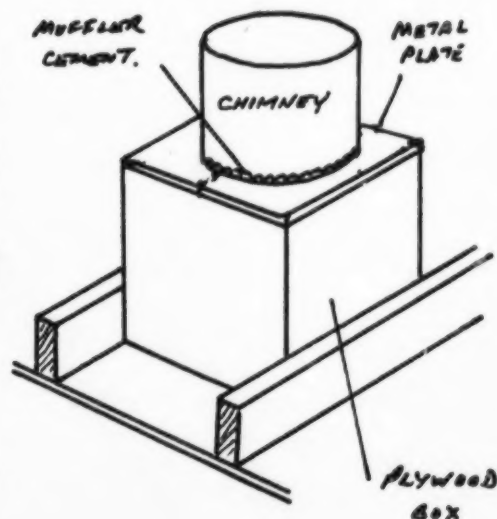
Sealing around vent stack:



Oakum was compressed into the gap around the vent stack, where it passed through the top plate of the plumbing wall. This technique gives a moderately good seal and allows some vertical movement of the stack due to expansion and contraction.

Sealing around the chimney:

A considerable air leakage path usually exists around chimney firestops at the ceiling level. The codes (as interpreted by Underwriters Laboratories) allow the chimney to be boxed in, provided that there is a minimum stipulated clearance to combustible materials. This means that the sides of the box must be well clear of the chimney if they are made of combustible material, and the top of the box, which comes into contact with the chimney, must be metal. Since insulation cannot be piled against the chimney, it is difficult to insulate the top of the box without using specialised insulation materials that are not normally available. As a result, there is some risk of condensation under the metal plate.

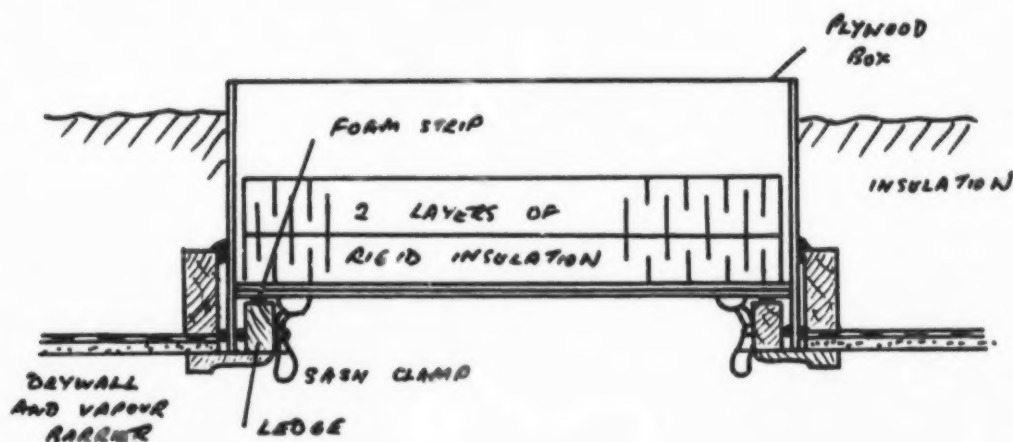


This problem can be avoided if the furnace is installed in a sealed furnace room. The air that exfiltrates around the upper firestop is then 'dry' air from the furnace room, and does not have enough moisture content to cause moisture damage in the attic. In this situation the box around the chimney serves only one purpose: to retain the increased thickness of ceiling insulation and prevent it from coming into contact with the chimney. In this instance a furnace room could not be fitted within the low-cost retrofit budget, and it was therefore necessary to install a metal lid on the box.

An open-topped box of plywood, with 400 mm clearance above the top of the ceiling trusses, was constructed around the chimney. All joints were sealed with caulk. A bead of sealant was run around the top of the box, and a split galvanised steel plate was nailed to the top of the box, making a tight fit around the chimney. The metal joint and the small gap around the chimney were sealed with muffer cement.

Attic hatch:

The existing hatch cover and trim were removed. Caulking was applied around the inside of the hatch frame, to make as good a seal as possible to the existing vapour barrier. A four-sided plywood box was then constructed inside the hatch frame, high enough to serve as an insulation stop for the increased level of insulation. The outside of the box, and the corners, were caulked to make airtight seals. A new ledge was installed around the bottom of the box to support the hatch cover. A continuous foam weatherstrip was attached to the top of the ledge. The hatch cover was cut to fit the new opening. Two layers of 50 mm rigid insulation were attached to the top of the cover with adhesive. Sash clamps were fitted to the cover, to pull it down tightly onto the weatherstripping.



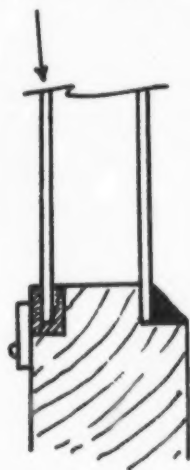
Insulation:

The contractors were asked to identify all places where the existing batt insulation was higher than normal, indicating possible air passages underneath. The batts were removed at these points, and placed at various places around the attic to double the existing level of insulation. Loose-fill glass fibre insulation was then blown in, to raise the thermal resistance to RSI 7.9. The insulation installer was allowed to pile the insulation against the eaves, and was asked to give a good fill in the areas where batts had been removed.

7.1 Assessment

The two exterior doors were thermal units (metal skinned with urethane foam interiors) with good quality weatherstripping. The front door was a solid unit, but had been poorly installed. It did not close easily and the weatherstripping was poorly adjusted. The rear, south-facing door had a glass insert, which provided useful solar gain. This door was fitted slightly better than the front door, but the weatherstripping needed adjusting. The sill weatherstripping on both doors showed signs of wear. In summary, the doors were good, but were probably losing more heat than they should, due to air leakage around the weatherstripping.

ALUMINUM-FRAMED
OUTER GLAZING



The windows on the main storey were double glazed with wood frames. The glazing was not a double hermetically sealed unit, but a fabricated version in which the inner pane was fixed and sealed while the outer one was fitted with an aluminum single glazing set into a rabbet in the window sash. The living room window consisted of three sections of fixed hermetically sealed glazing. The bathroom window was an awning type, and all other windows were fixed-awning types. The awning hardware was poor, and did not allow tight closure of the sashes. There were no sash locks, and the windows could be lifted easily off the seals when in the closed position. It was estimated that considerable air leakage could occur if the window sashes moved under the effects of wind loading.

The basement windows consisted of double-glazed awning types, with poor hardware and no weatherstripping. It was estimated that these would experience a significant amount of air infiltration.

7.2 Retrofit Alternatives

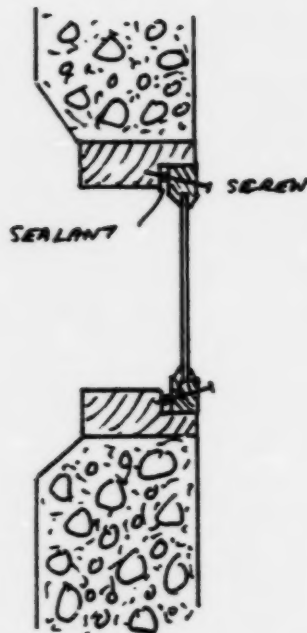
The doors were good from the point of view of thermal transmission, but poor from the point of view of air leakage. Their thermal efficiency could be increased significantly merely by the simple expedient of adjusting the weatherstripping seals and replacing defective ones. This was a low-cost option, and was therefore in line with the low cost strategy for this house.

Windows can be thermally upgraded either by adding extra glazing to reduce thermal transmission, or by improving the hardware and weatherstripping to reduce air leakage heat losses. The first option involves relatively high material and labour costs, and was out of the question in a low-cost retrofit. It was therefore decided to limit the retrofit work to low-cost

The awning windows were poorly weatherstripped, and there were no locking hardware to maintain good air seals when closed. The retrofit was therefore directed at these two features.

The basement windows lacked good weatherstripping and hardware. Since they were not really suitable as ventilation units it was decided to convert them to fixed-sealed units.

7.3 Details of the upgrading work



The two exterior doors were re-hung and adjusted to operate smoothly, and then were fitted with magnetic type weatherstripping.

The awning window sashes were opened. The window stops were cleaned and a continuous strip of foam weatherstripping was run around the stops to act as a compression seal when the window was closed. Two sash locks were installed on the bottom rail of each awning sash. The awnings were adjusted to give good seals when closed.

The basement awning windows were removed, and their hinges and sash locks were taken off. The window stops were cleaned and a continuous bead of sealant was run around the face of the stop. The window sashes were re-installed and pressed against the sealant. Finally, they were fixed in place by screws driven through the sash into the window frame.

8.1 Assessment

The furnace and DHW heater were about four years old and in very good condition. The furnace was rated at 38.5 kW input and 31.6 kW output capacity. The measured thermal efficiency was 66.2%, which was slightly lower than average for a furnace that was only four years in service. Further tests indicated that the combustion efficiency was high and the stack temperature was very high - suggesting that the poor efficiency was due to poor heat exchange. If this was correct, the efficiency could be improved slightly by tuning.

The DHW heater had a water capacity of 113 Litres and a thermal capacity of 8.9 kW.

8.2 Retrofit Alternatives

Neither the DHW heater nor the furnace were poor enough to justify replacement as a rehabilitation measure. Within the constraints of low-cost retrofit and the restrictions of the gas appliance codes, the only permissible retrofit work consists of tuning the furnace.

8.3 Details of the upgrading work

The furnace heat exchanger was checked, and any scale and rust were removed. The contractor was asked to inspect the fan and clean the blades, if dirty. The fan and motor bearings were oiled. The pulley belt was adjusted for correct tightness. A new filter was installed.

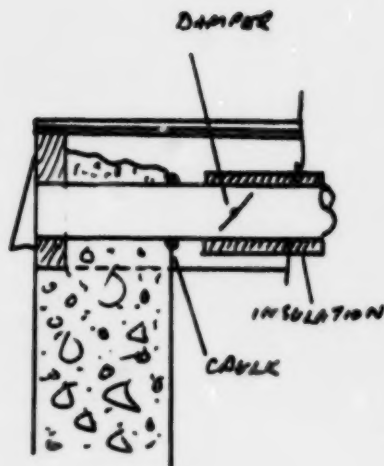
The furnace was given a final tuning by the adjustment of the burner air supply. The maximum thermal efficiency as measured with a furnace efficiency instrument was 68.3%.

The Moose Jaw Conservahome was the tightest of the six Conservahomes before retrofit, with an air change rate of 2.34 air changes per hour at a pressure differential of 50 Pascals, as measured by the air pressurization test.

It was estimated that the airtightness would be improved substantially by the air sealing work, a fact that was confirmed by pressurization tests conducted after retrofit. The test gave a result of 1.40 air changes per hour at 50 Pascals, showing a reduction of about 40% in the air leakage rate.

The test figure was comparable with those obtained in new energy-efficient houses with high levels of airtightness, and confirmed that the house would need a ventilation system to supplement the air change rate and maintain good air quality in the house.

Ventilation systems can be installed with various degrees of complexity and various cost levels, but for a low-cost retrofit the options are limited to a simple fresh air intake duct.



A fresh air vent was installed through the foundation wall on the south side of the house, and a 100 mm diameter duct, with a manual damper, was run from the vent to the return air plenum of the furnace. The duct was insulated to inhibit condensation on the cold exterior surface of the duct. Caulking was applied around the duct where it passed through the foundation wall.

This type of ventilation system has a number of shortcomings, but is the only low-cost option. In particular, the system tends to dump cold air into the air plenum, and this cold air can create zones of thermal discomfort in the basement area, if it escapes through a return air register in the basement.

The basement window sills were showing signs of moisture damage due to being located too close to grade level. This is poor constructional practice, and was remedied by installing metal window wells around the windows.

Downspouts were modified to give proper drainage onto splash pads.

"Duxseal" caulking compound was applied in and around the electrical conduits supplying electrical service to the house, and to an exterior outlet on the east wall of the house. This was to ensure an airtight seal around all electrical cables where they passed through the house envelope.

Damaged drywall, including discoloured drywall around some windows, was repaired and finished to match the existing paint.

Minor repairs were carried out on kitchen cabinets and electricals.

For details of costs, projected energy savings and conclusions about this project, the reader is referred to the Overview Report, which is the first in this series of reports.

For further details of the work, the materials and the techniques, the reader is referred to the following Appendix, which consists of the detailed specifications as given in the contract documents.

